POSCO High Mn Steels

I. POSCO Overview
II. High Mn Steel
III. Applications
IV. Summary

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Steel Solution Marketing Department
Founded in 1968, growing to a global company ...
The World’s Most Competitive Steel Maker

I. POSCO overview: POSCO History

Company Profile

- **Profile**
  - Established in 1968
  - 17,550 employees (2013)

- **Leading Steel Producer**
  - No.1 competitive Steel Company
  - No.5 steel production
  - 9th straight awarded (since 2010)

- **Highly Diversified Products**
  - Diverse mix from low-end (i.e. hot rolled steel) to high-end premium products

- **Strong Financials** (As of 2014)
  - Sales: USD 62 Billion
    (USD 27.6 Billion, POSCO only)
  - Operating profit: USD 3.1 Billion
    (USD 2.2 Billion, POSCO only)

Steel Competitiveness Ranking

<table>
<thead>
<tr>
<th>Ranking</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>POSCO (S. Korea)</td>
</tr>
<tr>
<td>2</td>
<td>Nucor (USA)</td>
</tr>
<tr>
<td>3</td>
<td>NSSMC (Japan)</td>
</tr>
<tr>
<td>4</td>
<td>Gerdau (Brazil)</td>
</tr>
<tr>
<td>5</td>
<td>Severstal (Russia)</td>
</tr>
<tr>
<td>6</td>
<td>Novolipetsk Steel (Russia)</td>
</tr>
<tr>
<td>7</td>
<td>JSW Steel (India)</td>
</tr>
<tr>
<td>8</td>
<td>JFE (Japan)</td>
</tr>
<tr>
<td>9</td>
<td>Hyundai Steel (S. Korea)</td>
</tr>
<tr>
<td>10</td>
<td>Erdemir (Turkey)</td>
</tr>
</tbody>
</table>

(*) score in: (1) skilled/productive worker, (2) pricing power in domestic market, (3) conversion cost/yield, (4) harnessing tech revolution, (5) size, (6) valued added product mix etc.
I. POSCO overview: Solution Marketing

**Definition**

**Global EVI Forum 2014**

- **2014** Application Technology
  - Forming technology
  - Painting technology
  - Welding technology
  - Parts evaluation

- **2015** Application Tech. + Commercial Support
  - Upgraded application tech.
  - POSCO family support
  - Downstream biz.
  - Steel solution marketing
  - Steel marketing
  - Steel production

**POSOCO the Great**
Unique properties of high Mn steels

- High stability of austenite
  - Good low temperature toughness
  - Non-magnetism
  - LNG tank and pipe, Non-magnetic equipment

- High work hardening rate
  - TWIP
    (Excellent strength & elongation)
  - Wear resistance
  - High resistance to blast
  - Automobile, Wear resistant equipment (Slurry pipe, Heavy machinery), Blast resistant door

- Low permeability of hydrogen
  - High resistance to hydrogen embrittlement
  - Hydrogen tank, Sour resistant pipe

- High fraction of ε-martensite
  - Excellent absorption of external impact energy (high damping capacity)
  - Damping (Floor panel, Ship, Steel stair)
TWIP steel for U-AHSS

- **High strength and excellent elongation for automotive parts**

- **Automotive Steels in POSCO**
  - AHSS, X-AHSS, U-AHSS

- **AHSS**: Advanced High Strength Steels DP, TRIP, CP, Martensite, etc.

- **X-AHSS**: eXtra-Advanced HSS
  - $25,000 \text{ MPa}\cdot\% < \text{TS}\times\text{El} < 50,000 \text{ MPa}\cdot\%$

- **U-AHSS**: Ultra-Advanced HSS
  - $\text{TS}\times\text{El} > 50,000 \text{ MPa}\cdot\%$

- **TWIP steel**: $\text{TS} 1,000\text{MPa}, \text{El.} 65\%$
III. Applications of High Mn steel: **Automotive**

**Applications of TWIP steel**

**Front crash part**
- No crack under axial compressive strain 75%
- Front part with the improved crashworthiness

**Bumper beam**
- World first application: FIAT (Italy)
- New Panda (FIAT)
- Bumper beam
- Weight reduction & cost saving
III. Applications of High Mn steel: Cryogenic service

Cryogenic high Mn steel

- **Chemical composition and mechanical properties**
  
  **Chemical Composition**
  
<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>Cr</th>
<th>S</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35~0.55</td>
<td>22.0~26.0</td>
<td>0.3max</td>
<td>3.0~4.0</td>
<td>0.01max</td>
<td>-</td>
</tr>
</tbody>
</table>

  **Mechanical Properties**
  
<table>
<thead>
<tr>
<th>YS(MPa)</th>
<th>UTS(MPa)</th>
<th>EI(%)</th>
<th>Charpy Impact Energy @ -196°C(J)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥400</td>
<td>800~970</td>
<td>≥22</td>
<td>Transverse: ≥22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Longitudinal: ≥41</td>
</tr>
</tbody>
</table>

- **Comparison with conventional cryogenic materials**
  
  **Strength and Toughness**

![Graphs showing strength and toughness comparison]

POSCO the Great
Application for LNG industry

**LNG storage tank**

- LNG carrier, LNG bunkering, on-shore terminal
- Total cost reduction about 30~50%

**Collaboration with customers**

- JIP: shipbuilding company & 5 class societies

### III. Applications of High Mn steel: Cryogenic service

- LNG carrier
- LNG bunkering
- LNG station
- LNG terminal
III. Applications of High Mn steel: Wear resistant service

Wear resistant High Mn steel

- Chemical composition and mechanical properties

  **Chemical Composition**

<table>
<thead>
<tr>
<th>Element</th>
<th>wt. % (Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.15</td>
</tr>
<tr>
<td>Si</td>
<td>0.5</td>
</tr>
<tr>
<td>Mn</td>
<td>5.0</td>
</tr>
<tr>
<td>P</td>
<td>0.015</td>
</tr>
<tr>
<td>S</td>
<td>0.008</td>
</tr>
<tr>
<td>Ceq</td>
<td>0.63</td>
</tr>
</tbody>
</table>

  **Mechanical Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (mm)</td>
<td>10~70</td>
</tr>
<tr>
<td>Hardness (HB)</td>
<td>400</td>
</tr>
<tr>
<td>Y.S (MPa)</td>
<td>1,000</td>
</tr>
<tr>
<td>T.S (MPa)</td>
<td>1,200</td>
</tr>
<tr>
<td>El. (%)</td>
<td>12</td>
</tr>
<tr>
<td>CVN(-40°C) (J)</td>
<td>10~30</td>
</tr>
</tbody>
</table>

- Bending and welding properties

  **Bending Property**

  Excellent bending property is required for buckets.

  **Welding Property (CTS test)**

  - 17kJ/cm²/SM-70G Solid Wire
III. Applications of High Mn steel: Non-magnetic material

Non-magnetic High Mn steel

- **Chemical composition and mechanical properties**

<table>
<thead>
<tr>
<th>Chemical Composition</th>
<th>wt. % (Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.3–0.5</td>
</tr>
<tr>
<td>Si</td>
<td>0.3</td>
</tr>
<tr>
<td>Mn</td>
<td>22–26</td>
</tr>
<tr>
<td>P</td>
<td>0.03</td>
</tr>
<tr>
<td>S</td>
<td>0.01</td>
</tr>
</tbody>
</table>

- **Mechanical & Magnetic Properties**

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>YS (MPa)</th>
<th>TS (MPa)</th>
<th>El. (%)</th>
<th>Bending (180°, r=2t)</th>
<th>Magnetic Permeability ((\mu))</th>
</tr>
</thead>
<tbody>
<tr>
<td>4–40</td>
<td>350</td>
<td>800–970</td>
<td>22</td>
<td>Passed</td>
<td>1.002</td>
</tr>
</tbody>
</table>

- **High strength and good magnetic property**

  - **Comparison of Strength & Magnetic Permeability**

  ![Graphs showing the comparison between high Mn non-magnetic steel and Type 304 stainless steel](image)